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(54) VACUUM GAUGES

(71) We, BOC INTERNATIONAL LIMITED, (formerly the British Oxygen Company Limited), an English company, trading as EDWARDS HIGH VACUUM INTERNATIONAL) of Manor Royal, Crawley, Sussex, England, an English company, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to vacuum gauges, and particularly to the type known as Penning gauges, which are cold cathode ionisation gauges, in which a magnetic field is used to lengthen the electron path, and thereby increase the number of ions produced.

Ionisation gauges rely for their operation on ionising the atoms and molecules of the gas of which the pressure is being measured by bombarding the gas with electrons of high energy. The electrons are energised by subjecting them to strong electric fields.

To initiate a discharge, some free electrons must be present within the gauge envelope and a certain number are likely to arise due to random events. Free electrons are accelerated towards the anode by the applied potential gradient. There is a probability that some will make collision with residual gas molecules, producing ionisation of the molecules and the release of further electrons. The newly-released electrons will be similarly accelerated and may produce further gas collisions, ions and electrons. The ions arising from electron collisions will be accelerated towards the cathode and, when they strike it, may cause the release of further electrons by secondary emission processes.

For a discharge to be built up and sustained the rate at which new free electrons are generated, by collisions within the gas or by secondary emission, must initially exceed the rate at which electrons are captured by the anode. Unless free electrons are produced at a greater rate than the capture rate then the discharge will fail to establish itself.

When the discharge is fully established it stabilises at a level such that the flows of ions and electrons to the cathode and anode respectively reach a value which is dependent on the number density of gas molecules within the discharge chamber of the gauge, and thus the ion current may be used as a measure of the gas pressure.

When a gauge of the type described above is switched on at a low pressure it may fail to "strike" (i.e. a discharge may fail to establish) for a considerable time. At low pressures the chance of randomly-occurring free electrons is reduced, as also is the chance of such electrons making numerous collisions with residual gas molecules, so that they produce less ions and additional electrons in their journey to the anode.

The difficulty discussed above is greatly accentuated if the electrode structure of the gauge (particularly the cathode) has become coated with contaminating layers. Such contamination can very greatly reduce the probability of secondary electrons being emitted as a result of the bombardment of the cathode by gas ions. Electrons produced by secondary emission are often of great importance for the proper establishment of a discharge after the gauge is switched on at low pressures.

Vacuum gauges of the type being discussed are very frequently employed in association with industrial high vacuum systems where many sorts of contamination, including organic vapour contamination, may enter the gauge head from the pumping system. Organic vapours may become adsorbed onto the electrode surfaces, which may affect their secondary emission characteristics. Due to the continuous bombardment of the electrodes by charged particles, adsorbed organic layers may be chemically modified to produce polymerised layers of solid contaminant which may progressively grow thicker as contamination proceeds. Such contamination is particularly effective in inhibiting the

proper establishment of the discharge when the gauge is switched on under vacuum conditions, and is a common cause of difficulty in the application of these gauges for industrial systems. Regular and tedious cleaning of the gauge electrode structures may be necessary.

It is a known technique to include in the discharge chamber of the gauge a source of charged particles, for example, a body of radioactive material, and this may be supported from the anode or from the cathode structure, the best site depending on the type of radioactive material selected (a source of alpha particles would best be associated with the anode and of beta particles with the cathode). Even a weak such source can emit charged particles in such abundance that adequate free electrons are produced in the ionisation chamber to ensure the rapid establishment of a discharge even though the gauge structure is considerably contaminated.

The use of radioactive material in the manner described above is not a complete solution to the problem of ensuring reliable establishment of a discharge, because of the possibility that the radioactive source itself may be affected by the accumulated contamination in the gauge by physical masking by polymerised layers. For example, a very convenient radioactive material is thoria, which is a source of alpha particles and which is appropriately mounted on the anode. A layer of thoria can be conveniently applied over part or all of the anode surface. However, the anode is particularly prone to contamination by the accumulation of polymerised layers arising from the organic vapours entering the discharge space, and the thoria coating can become buried and its effectiveness very greatly reduced. If mechanical cleaning of the anode is attempted it is probable that the thoria layer will be removed along with the contamination.

If the gauge can be designed so that a region providing suitable sites for the mounting of a radioactive source can be provided on the side of the discharge chamber remote from the vacuum system, and so that contamination could reach the source only after passage through the discharge chamber, then the source would, in large measure, be protected from the most troublesome types of system-arising contamination because organic vapours migrating from the system would tend to be ionised, trapped and polymerised in the intense discharge in the discharge chamber, and the region beyond would experience a greatly-reduced migration of contaminating vapours.

Accordingly the present invention provides a high vacuum gauge of the cold cathode ionisation type employing a magnetic field to lengthen the electron path, including at least one radioactive source of charged particles positioned within the gauge but outside the discharge chamber thereof and on the side remote from the gas inlet of the gauge in such a manner that gases and vapours from the gas inlet cannot reach the source of charged particles without traversing the discharge chamber.

According to a preferred feature of the invention the said source is located in a region where magnetic field intensity is low compared with that in the discharge chamber so that any discharges arising are less intense.

According to one feature of the present invention, the radioactive material is in the form of a layer of material coated or otherwise deposited on a normal component of the gauge.

The present invention will now be described by way of example with reference to the accompanying drawing, which is a diagrammatic axial section of the basic components of a Penning gauge of the present invention.

The measuring head 2 of the Penning gauge comprises basically a hollow cylindrical body 4 of metal of which the interior is in communication with the equipment 5 being evacuated and of which the gas pressure is to be measured.

The inner bore of body 4 is formed near one end with a circumferential step 6 against which abuts one of three cathode cups 8. Each cup has a cylindrical wall 10 and a planar end wall 12. All the end walls are perforated, as at 14, to allow gas to flow to and from the interior of the gauge head 2 so that the pressure in the interior of the gauge head is always the same as that in the associated evacuated equipment 5.

Extending coaxially along the interior of body 4, and into the interior of the discharge chamber 7 defined by the two opposed cathode cups 8, is an anode 16 extending from an end cap 18 which is secured to the outer end of the body 4 by means of a nut 19.

Trapped between the end cap 18 and bevelled inner edges of the respective end of body 4 is an O-ring 21 designed to make fluid-tight the contact between end cap 18 and body 4.

Extending between the end cap 18 and the nearest cathode cup 8 is a compression spring 20, which is effective to bias the three cathode cups axially into contact with each other and against step 6.

As can be seen from the drawing, the anode 16 extends through central apertures 22 in the cathodic end walls 12 which are nearer to cap 18. For the gauge to operate, a direct potential difference of the order of 2.5 kV is established between anode 16

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and the cathode cups 8 by means of a high tension source 23 in series with a switch 25. The size of the apertures 22 is chosen so that the radial clearance between anode 16 and the edges of these apertures is sufficient to ensure that a steep potential gradient is established across this gap without its exceeding the breakdown potential of the gap.

Although these are not shown in the drawing, it will be understood by vacuum experts that means associated with the gauge head 2 will be provided to measure the ion current which would arise by the flow of ionised molecules between the electrodes under the influence of the electric gradient. Positioned around the exterior of body 4 there is a permanent magnet 27 adapted to apply a high-intensity magnetic field directed substantially parallel to the axis of body 4 and anode 16 in the interior of the cathode cups. The effect of this magnetic field is to cause electrons or other charged particles passing between the electrodes to travel in spiral paths. This thus causes the electrons in particular to travel for far longer distances in the interior of the discharge chamber, before being captured by the cathode, than would be the case if the electrons travelled merely radially, as they would in the absence of the magnetic field. This considerable extension to the length of the path of the electrons increases significantly the chances that an electron will hit and ionise a gas atom or molecule before it is captured by the anode. However, as already mentioned, at high degrees of vacuum, when the electric field is first applied (by closing switch 25), there may be insufficient electrons to give rise to a sufficient number of ionising collisions to produce a discharge and for the gauge to start indicating properly. Thus, in accordance with the present invention, quick "starting" of the gauge is ensured by providing continuously sufficient charged particles in the discharge chamber to initiate ionising collisions.

The anode 16 is mounted on end cap 18 by means of an insulator in the form of a glass bead 26 which is sealed to both the anode 16 and the end cap 18 in a fluid-tight manner.

The collisions of the ionised atoms or molecules with the inner surface of the cathode cups 8, in addition to giving rise to the ejection of secondary electrons, also causes the material of the cathode cups to be sputtered. This material tends to be deposited on other components in the interior of the gauge head. Because this sputtered material is electrically conductive it is important to ensure that it does not fall on the surface of the bead 26 which is internal of the gauge head because, if it were to do so, the resultant metal film would short-circuit the electric discharge by connecting the anode electrically to cap 18. To prevent this, a shield 28 is threaded on anode 16 and is held in place by means of a spring washer 30. The shield 28 is cup-shaped and its edges are spaced sufficiently from end cap 18 to ensure that the potential gradient between shield 28 and cap 18 is less than the breakdown potential of the gas.

In the illustrated gauge head, the charged particles are provided by a source of radioactive material applied as a coating to one or other component of the gauge. One material which has been found to be particularly suitable for such an application is thoria, which is the oxide of the radioactive element thorium. Because thoria has a radioactivity of only 0.002 μCgm^{-1} it is sufficiently safe to be used without any stringent precautions against its radioactivity being necessary. Although the thoria could be applied as a coating to the length of anode 16 within the discharge chamber, it has been found that this is disadvantageous, as has been explained above. It is the feature of the present invention that the thoria is applied as a coating to a component (or part thereof) which is positioned outside the discharge chamber 7 of the gauge so that it has a greatly-reduced chance of becoming contaminated.

In a preferred embodiment of the present invention the coated component is the insulator shield 28.

Thoria is a source of alpha-particles. These can be regarded as high-speed doubly positively charged atoms of helium stripped of their electrons. These particles, after emission from the external coating on shield 28, move under the influence of the electric fields between the anode 16 and the gauge envelope 2, cathode cups 8 and other earthed components. Some will enter the interior of the discharge chamber 7 through the perforations 14 and apertures 22, thereafter striking the interior walls of the discharge chamber. Others will strike surfaces at gauge envelope potential without entering the discharge chamber. The electric fields employed ensure that whereever an alpha particle collides with a surface it ejects on average at least one secondary electron which then starts to travel to the anode with the chance of colliding with gas molecules during transit. The discharge is thus reliably established.

Thoria has a half-life which is sufficiently long for the level of radioactivity thereof to remain sufficient for a time which is significantly greater than the operating life of the gauge.

In an alternative form of the present invention, the source of radioactive material could be of some element other than thorium. For example, it could be in the form of a length of radioactive nickel wire

positioned in the bottom of a peripheral groove in the inner surface of the wall of body 4 on the side of the cathode cup 8 remote from the gas inlet 31. The radioactive isotope of nickel is Ni63, which functions principally as a source of beta-radiation.

In practice the radionickel source would be sealed from direct contact by those assembling or using the gauge. In one preferred method of construction the source takes the form of pure nickel wire having no radioactivity. This core wire is coated uniformly with a layer of radionickel 63, which in turn is coated with a thin layer of inert nickel. The outer layer prevents the radionickel from being touched, and yet is not too thick to prevent the beta-radiation from being emitted by the source and acting as a source of charged particles facilitating quick starting of the gauge.

In order to prevent the source of radioactivity from being viewed externally of the gauge head, when the end cap 18 is removed, the source is kept captive in the bottom of the groove in which it is seated, as by nipping in the outer parts of the walls of the groove to prevent the wire from being displaced by the normal gravitational and accelerational forces to which it would be subjected during normal handling and usage of the vacuum gauge. The radial depth of the groove is appreciably greater than the radial thickness of the wire so that the beta-radiation is forced to pass in a narrow fan-shaped beam across the interior of the cathode, with the walls of the groove acting to prevent any radiation from passing substantially axially along the length of body 4.

Accordingly, it will be seen that the present invention provides a cold cathode vacuum gauge in which radioactive material is used to ensure that sufficient charged particles are present at all times, irrespective of the gas pressure in the gauge, so that a satisfactory discharge is quickly established when the gauge is energised, the radioactive material being sited in a region outside the main discharge area and where the discharge is relatively less intense and in a region such that system-arising contamination would have to traverse the main discharge area before it could encounter the radioactive material.

WHAT WE CLAIM IS:—

1. A high vacuum gauge of the cold cathode ionisation type employing a magnetic field to lengthen the electron path, including at least one radioactive source of charged particles positioned within the gauge but outside the discharge chamber thereof and on the side remote from the gas inlet of the gauge in such a manner that gases and vapours from the gas inlet cannot reach the source of charged particles without traversing the discharge chamber.

2. A high vacuum gauge according to claim 1, wherein the said source is located in a region where the magnetic field intensity is low compared with that in the discharge chamber so that any discharges arising are less intense.

3. A high vacuum gauge according to claim 1 or 2, wherein the said source is a body of radioactive material.

4. A high vacuum gauge according to claim 3, wherein the said body of radioactive material is in the form of a layer of material coated or otherwise deposited on a normal component of the gauge.

5. A high vacuum gauge according to claim 4, wherein the said normal component of the gauge is a shield which prevents material sputtered from the cathode from being deposited on an area of the inner surface of the gauge in the vicinity of the anode, thereby to avoid electrical connection of the anode to the cathode.

6. A high vacuum gauge according to claim 3, 4 or 5 wherein the radioactive material is thoria.

7. A high vacuum gauge according to claim 3, wherein the radioactive material is the radioactive isotope of nickel.

8. A high vacuum gauge according to claim 7, wherein the radioactive material is in the form of a wire.

9. A high vacuum gauge according to claim 8, wherein the wire has a core of nickel having no radioactivity coated with a uniform coating of radioactive nickel, which coating is in turn coated with a thin layer of nickel having no radioactivity whereby the radioactive nickel cannot be touched but acts as a source of beta particles.

10. A high vacuum gauge according to claim 8 or 9, wherein the wire is positioned in a peripheral groove in the inner surface of the gauge.

11. A high vacuum gauge substantially as hereinbefore described with reference to, and as illustrated in, the accompanying drawings.

For the Applicants,
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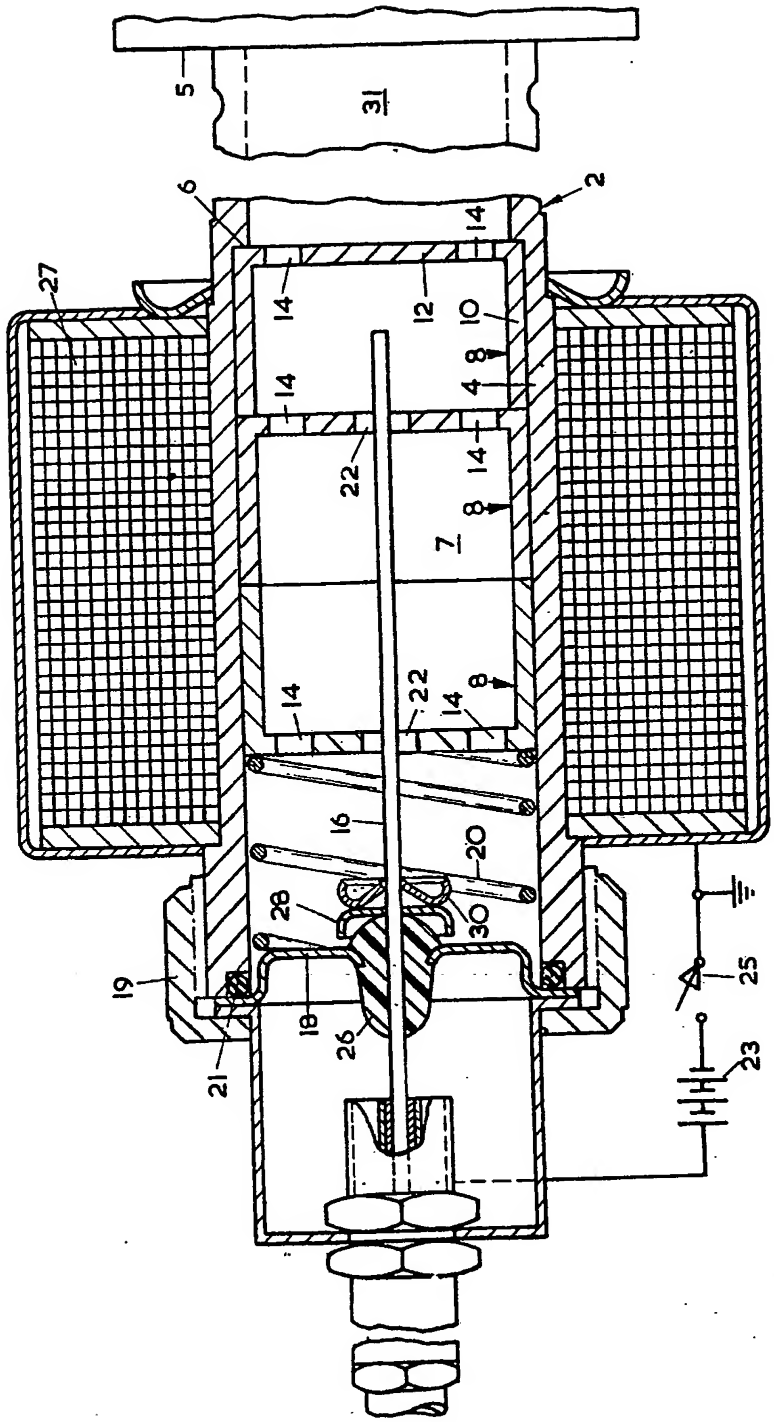
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